DOCUMENT RESUME

ED 457 157 SP 040 261

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TITLE Teachers' Responses to Science Writing.
PUB DATE 2001-00-00
NOTE 15p.
PUB TYPE Reports - Research (143)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Elementary Education; *Science Instruction; Teacher Attitudes; Teaching Methods; *Writing Across the Curriculum; *Writing Skills
IDENTIFIERS *Science Writing

ABSTRACT

This study asked four experienced teachers to respond to elementary students' science writing and explain their thinking, discussing factors they considered as they made the choices that ultimately supported or undermined children's attempts to write about science. Teachers responded first in writing, then orally expanded on written comments during an interview. Teachers were visited twice more to discuss transcripts of the comments and explore ways the issues surrounding science writing related to general practices and philosophies discussed in the first interview. Overall, no two teachers defined or used science writing in the same ways. Teachers' individual definitions of science predisposed them to either accept or reject the processes of science writing as supportive of science learning. Most teachers considered responding to the science writing a frustrating process. All of the teachers assumed the students could read and write nonfiction science paragraphs and were uncomfortable with evidence that this might not be the case. The three female teachers regarded science writing as qualitatively different from other nonfiction writing. The teachers' need for external support in science teaching and assessment defined the range of activities which they included in science instruction. (Contains 28 references.) (SM)

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Caroline V. Owens

Teachers' Responses to Science Writing

by

Caroline V. Owens

ED 457 157

Introduction

In the past decade, professional literature has been inundated with articles concerning the potential uses of writing in all areas of the curriculum. Science educators have explored the "Reading-Science Learning-Writing Connection" (Holliday, Yore, & Alvermann, 1994) and its potential for transforming science education (Rivard, 1994), redefining science literacy, and increasing the proportion of scientifically literate members of our society (NRC, 1996). Implementing a curriculum that includes developing science knowledge through writing, however, relies upon the interest and ability of millions of individual teachers to facilitate scientific communication in the classroom. There is at present no evidence to support an assertion that typical teachers are prepared to encourage and interpret science writing in ways that support science learning.

This study asked experienced teachers to respond to science writing and then to explain their thinking. What factors did they consider as they made the choices that ultimately supported or undermined children's attempts to write to learn science? Comparing observations, written responses, and oral discussions generated broad interpretive themes, used to organize data for presentation, that personalized the dimensions of teacher actions in the face of administrative mandates for curricular change.

Review of Literature

Teaching science through writing rests on assumptions that science language, like all language, is epistemology (Halliday, 1993; Wells, 1994) with socially negotiated meanings (Driver, Asoko, Mortimer, & Leach, 1994; Vygotśky, 1978). Most children and adults, however, are uncomfortable with technical language forms, and prefer everyday narrative as a way of communicating all but the most abstruse of science ideas (Bruner, 1986; Gallas, 1994; Halliday, 1993; Barlow, 1997). It follows that effective science teachers must guide students to interpret the language forms of scientific communication as well as the vocabulary, delicately balancing the role of contextualizing conventional theory with experiences and analogies while attempting to avoid the misconceptions concealed in everyday language (Driver et al., 1994; Solomon, 1985; Wells, 1994). This is especially true in the elementary years, when teachers actively participate in children's efforts to read and write in the content areas.

Although the dichotomy is incomplete, it is useful to consider science writing in elementary classrooms as falling into two broad categories. The more familiar form, writing *about science*, is a process of telling knowledge, of synthesizing the ideas of others and presenting these to an informed audience (the teacher) to demonstrate recall and mastery of conventional understanding of the subject. This form of writing uses a distant voice and discipline-specific terminology. Practitioner literature encourages teachers to use writing *about science* as a way to assess science knowledge (e.g., Aram et al., 2000; Fay, 2000; Meiber, 2000; Smith & Wesley, 2000). There is in this practice an unstated assumption that the knowledge of the student is closely correlated with the content of the written product.

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The age at which children develop accuracy and consistency in representing their scientific thinking has not been established, however. Most children explore science ideas through oral language long before they attempt to give permanence to their thinking by placing it on paper. Until roughly the age of nine, even oral statements of science relationships are difficult for most children to create independently (Halliday, 1993). Teachers confirm that although graphic representations of thinking support science talk, the science conversations of children reflect a content and complexity not present in their writing (Fellows, 1994; Gallas, 1994; Gallas 1995; Owens, 1999a, b). It appears that, for elementary science students, writing to tell about knowledge is, at best, a remote static indicator of a dynamic process of conceptual development. Nevertheless, it remains the dominant form of writing in classrooms.

While much has been written in professional journals about practices supporting writing *about science*, there is little information available to teachers about practices supporting a second kind of writing, in which the writing process itself becomes a way to learn science. This is writing *to learn*, in which students make their conceptions explicit, then review and edit them in the light of developing interactions with materials, text, and other people (Owens, 1996).

The information teachers take from writing *to learn* science may come from the word choices, as is true in representational text, but is also derived from the presentation itself. The texts created by students who are writing *to learn* are often composed in an active voice using the first person and, in the case of elementary school writers, everyday language rather than terminology (Owens, 1996, 1999b), pictures as well as words, and various informal idiosyncratic symbols devised by the writer (Peasley, 1992). Writing *to learn* often appears in learning logs, journals, and formative drafts of reports. Expressive science writing provides teachers with information that supports teaching decisions rather than summary assessments.

Although superficially similar, as both involve writing and the subject is science, writing *to learn* and writing *about science* differ in important ways. Writing *about science* is a process of transmission that begins with decontextualized theories of Western science and places the writer's sentences in relation to this. Writing *to learn* is a constructivist process that begins with the child's expression and progresses toward more conventional science knowledge through a gradual refinement of language and organization.

Although superficially similar, as both involve reading and responding to children's writing, the teaching stances that support the two forms of science writing also differ in ways teachers may not recognize or choose to implement. Supporting writing *about science* involves adopting a stance of expert knowledge from which the teacher provides feedback to indicate how closely student writing corresponds to adult science. Teacher actions associated with writing *to learn* include questioning, reflecting, clarifying communications, facilitating interactions, and providing accurate and timely feedback concerning both the content of student writing and the manner in which ideas are expressed. These come from a teacher who is a co-learner, engaged with each child in the construction of meaning through clarification of communication.

Methodology

Sample. This study began when Ellen, a gifted fifth-grade teacher with a passion for process writing in the content areas, mentioned a co-worker's complaint about Writing Across the Curriculum. He was, he said, a sixth grade science teacher. What did writing have to do with his

class? His question suggested a case study approach, as the phenomenon of interest (responding to science writing) could be studied as a bounded unit within the larger natural context of schools and schooling (Merriam, 1998).

Ellen, Tammy, Jim, and Claudia were all teachers for a school corporation serving the children of a Midwestern county in which a large state university was located. I asked for volunteers at a district-wide inservice session concerning writing in the content areas. From an initial pool of seventy, Ellen, Tammy, Jim, and Claudia were selected to give a broad representation of levels of knowledge and interest in language, science, and upper elementary level teaching (see Table 1). Ellen had moved to a language-based approach to teaching long before the district required it; she fell near one end of a continuum of child-centered practice. Jim's teaching was mostly teacher-centered, placing him at the opposite end. Tammy and Claudia's practice fell between the two.

Table 1. Participants' College Science Courses' Intermediate Experience and Interest in Science Writing

Teacher	Courses	Years	Interest
Ellen	6	7	very high
Jim	3	23	very low
Tammy	1	2	none
Claudia	4	14	high

As Charmaz (1991) pointed out, effective interviewers "must try to see the issues discussed and the immediate interaction from the respondent's perspective—that is, to adopt the respondent's role and look at the situation from his or her perspective instead of the reviewer's" (p. 388). To enact this, I visited the teachers in their classrooms four times for periods of thirty to sixty minutes per visit. Interviews were casual, loosely structured to probe responses to a broad guiding question. I began the first interview by asking about the classroom. How did the teachers see their classrooms relating to individual teaching philosophies?

Ellen

Ellen had seven years' experience teaching fifth grade. She hoped that hers was a classroom where children and adults could share ideas without fear of judgment. She maintained an intentionally democratic atmosphere in which students determined much of the curriculum through self-chosen topical explorations. "I just don't think they learn if there's not some choice involved."

Ellen taught in a 350-student upper elementary school in an area of university student and faculty homes. Her classroom was large, with an open central carpet surrounded by tables seating five to seven children apiece. Small toys identified the individual workstations of the 28 students. Sets of books were placed along the walls in boxes with hand printed labels indicating the topic of the text set. Racks of paperback books and magazines filled the corners, and the walls were lined with pictures, posters, and reports written by the students.

After teaching preschool for several years, Ellen completed a degree in elementary education with a minor in science education. Her classroom was a frequent site for demonstration lessons, practice, and student teaching placements for the state university. Ellen's science teaching included twice-weekly use of the materials-based Piagetian science program supplied by the school district, science journals, and written reports of individual science research.

> I've always used writing as a way to learn. When you write about something, you have to be thinking. They [students] can do activities all day and not think about anything, but they CAN'T write all day without putting in thought. And they can't give feedback without at least reading what the other person wrote.

Jim

Jim was a sixth grade science specialist at a large school on the west side of the county, in an area of blue-collar, agricultural, and day laborers and their families. He completed a bachelor's degree at the local university in 1972 and was subsequently hired to teach sixth grade in a self-contained classroom. During his first six years of teaching he completed a master's degree and moved into his present position.

Jim's classroom was at the end of a long corridor in a basement hallway. Below the wall of chest-high windows was a bank of empty shelves. Closed metal cabinets flanked the entry door. Jim's desk was placed in the front of the room, next to a table covered with science apparatus. A periodic table of the elements hung above the front chalkboard, and a taxonomic diagram hung above the back chalkboard. The tan walls were otherwise bare. On low shelves behind the demonstration table were thick textbooks.

In class each day, students reviewed homework, read sections of a chapter aloud, and listened to a lecture Jim read from notes kept in a worn three-ring binder. As one day's lecture ended, he turned to the next page "so that it would be ready for tomorrow, just in case I had a sub or wasn't feeling well." Following the lecture, students answered the appropriate questions in the end-of-chapter test. Once a week, the students conducted an experiment with the prepared materials kit supplied by the textbook publishers and filled in a short-answer worksheet. Each Friday, Jim gave a multiple-choice quiz over the current chapter.

> Kids need to see science to believe it. They need to be doing a lot of hands-on work with these materials. That's when I can see those light bulbs going on and I just know they've learned something new. They tell me about it every Friday.

Tammy

Tammy completed a bachelor's degree in early childhood education at a private college in the northeast. She taught part-time in a kindergarten for a few years, then petitioned for elementary licensure. When she moved to the Midwest, her elementary licensure was transferred to the new state. At the time of the study, Tammy had been teaching fourth grade for two years in a rural elementary school in the far southeastern part of the county. Development pressure from the neighboring blue-collar communities had swollen the school beyond its physical capacity. Tammy's class, housed in a doublewide trailer, contained 31 students. Twenty-six desks were arranged to form worktables for four to six students. Each cluster of desks had an extra chair and a plastic crate containing books, papers, and a pencil box for an additional student.

Manufactured posters illustrating spelling and punctuation rules with anthropomorphic animals hung on all four walls. One red-bordered bulletin board contained carefully filled in coloring book pages beneath the heading "All Kinds of Animals." A smiling earthworm, standing upright, held a sign in a tiny hand that read, "How many bones do YOU think I have?"

Tammy taught science on Fridays just before dismissal. She used a student materials kit for demonstrations, reading aloud the scripted questions. "I don't think we have time to get out all this stuff. And anyway, there's not enough for all these kids."

The weekly worksheets were graded by a senior citizen volunteer because Tammy did not feel she had time to correct student work. "It's hard just fitting in science class, let alone grading all this stuff. I can't even meet with all my reading groups in a day. Doing more just isn't a possibility."

Claudia

Claudia had been teaching in the district's upper elementary classes for fourteen years. Her first few years were spent in the same school in which Ellen now teaches, and since that time she had not taught more than three consecutive years in any single school. At the time of the study, she was in her first year teaching at a rural elementary school on the far east side of the county. Eleven fourth-graders and six fifth-graders sat at long tables around the perimeter of the room. Over each seat hung a branch from which dangled pictures, book titles, seashells, and other personal memorabilia. An index card was stapled to one: "Hey Mom!!! This is who I AM!!!!!" The open center of the room was carpeted. At one end sat a wooden rocker and a basket filled with novels, composition books, and writing supplies.

Claudia liked science in high school, but abandoned hopes of becoming a junior high science teacher when she failed an introductory college chemistry class. Much of her teaching contained references to science and technology in everyday life, on television, or in political decisions such as the siting of a new county landfill.

> I think you have to use everything you can to teach about science. They're already thinking about these things, I just let them use it for school. ... Writing? We write about everything from the landfill to our pets! These kids just want someone to listen to them!

Procedure. The teachers were shown three pieces of science writing gathered at various points during a topical writing project in Ellen's class. THE SUN (Figure 1) is an example of a very early draft, virtually copied from source books. INSECTS (Figure 2) was a list of preliminary thoughts from a student's science journal. OCEANS AND THINGS LIVING IN THEM (Figure 3) was a piece the young author regarded as complete. None of the students were particularly gifted writers; none had identified learning difficulties.

Ellen's comments were returned to the students as part of their classroom instruction. The anonymized pieces, edited to remove clues to the author's gender and ethnicity, were given to Jim, Tammy, and Claudia shortly after my first visit to their classrooms. Each teacher was informed the samples were written as assignments for a fifth grade science class. They were asked to give feedback to "help the writer to learn science through writing."

THE SUN

The sun and planets were probably formed from a vast cloud of gas and dust, about 46 billion years ago!! It is the closest star to earth. If the sun were hollow, it would hold 1.3 million earths!! It's about 860,000 miles wide in diameter.

The location of the sun is in the middle of the solar system. It is 93 million miles away from the earth. It takes one year for the earth to go around the sun. It's about 3 million degrees (F). It will burn out 5-10 billion years from now (That's what scientists say). Sunshine is hydrogen converted into helium. The sun reflects off the moon to make the moon shine. That's all I have to say about the sun.

Figure 1. The Sun.

INSECTS

Fireflies are beetles, Insects have three body parts, An insect eye has many lenses. People use many kinds of insects for tools: bees' stingers can be used for nails. I had always thought that spiders were insects but you know what, they're not!

There are more than 6000 kinds of ants, Hickory Horned Devil Caterpillars nibble of their eggs to gain strength, Butterflies and moths come out of their cocoons at night, Butterfly wing colors are made out of powder,

Snails have no arms, legs or bones!

Grasshoppers have strong legs,

A queen bee may live 2 or 3 years,

Queen bees lay almost half a million eggs in one lifetime, A beehive may have thousands of bees in one colony, Most bees depend on their stinger to fight back. A honey bee has hair, Some killer bees live in Florida. Killer bees travel 300 miles a year,

Roaches can run real fast.

A female praying Mantis is bigger than a male, Praying mantises can lay over 300 eggs in one sack!

Only female mosquitoes suck blood.

Figure 2. Insects.

OCEANS AND THINGS LIVING IN THEM
(excerpt)

Fish rely on their sense of smell to locate food, evade enemies, navigate through river systems and find sexual partners. Their sense of smell is a chemical system triggered by odors. They can smell things dissolved in water. Fish have taste buds covering the tongue, the roof of the mouth, throat and in some fish the lips and outer body surfaces. Like humans fish can tell apart sweet, bitter, and salty tastes. What I think is a fish is it breathes water, they have a swim bladder and have fins. There are five different kinds of fins counting the tail. The pelvic, anal, spiny dorsal fin, soft dorsal fin, and the tail fin.

Figure 3. Oceans and things living in them.

The teachers responded first in writing. Within a week of interpreting the student samples, each teacher was asked to orally expand on written comments during an on-site interview. Two additional site visits were made, one to talk through a transcript of the discussion of the written comments and a second to explore ways the issues surrounding science writing related to the general practices and philosophies discussed during the first interview. The teachers reviewed each transcript, making minor changes when they felt the meaning was unclear or inaccurate. As data collection progressed, it became apparent that these were teachers who wanted to talk about teaching. Claudia and Ellen surprised me by phoning at least once a week to discuss new, relevant readings and conversations they had had with other teachers.

Data Analysis. Qualitative studies of teachers, students, and professional actions are fraught with inconsistencies simply because they are produced through human interactions. Interviews are, by their very nature, "not precise, definite, objective, clear, predictable, measurable, or repeatable" (Beer, 1997). In this study, teachers spoke and wrote about children's writing, and I collected their communications, which would seem to be a clear chain of transmission of the ideas of the participants. But, as Laurel Richardson points out, "Language does not reflect social reality, but produces meaning, creates social reality" (1998, p. 348). As I analyzed the verbal and the nonverbal content of our interactions, I made deliberate attempts to minimize my interpretations, to stay close to the data. Even so, when the teachers reviewed paragraphs and transcripts, they found (and corrected) passages in which the social reality I came to articulate was not what they intended.

Observational and interview data were initially organized by source. When this became cumbersome, I developed a rough classification of the substance or topic of the conversation or observation. For example, at one point I had separate files for material relating to general teaching methods, undergraduate courses, education courses, textbooks, materials, time, curriculum, grading, making assignments, writing style, special education, topics, other teachers, room decorations, school layout, administrator comments, workshop notes, student characteristics, and standardized tests. Over time, this was collapsed into a third categorical scheme consisting of eight broad themes.

Each teacher's written response to an individual piece of writing was compared to oral discussion of how the response was formulated. Observation of the environments created by each teacher provided additional insight into their beliefs about teaching. Similarly, all written responses were analyzed together, and all interview data were considered as a group to allow triangulation by method as well as source (Bickman & Rog, 1998; Denzin & Lincoln, 1998; Lincoln & Guba, 1985). Like a series of transparencies, these incomplete data sources were laid atop one another to give a detailed and cross-referenced image of beliefs and actions that related to science writing.

The data were analyzed by constantly comparing information obtained through different methods and from different participants. As patterns emerged across teachers or among themes, the remaining data were searched for disconfirmatory as well as confirmatory evidence. The eight themes were condensed to form four broad categories of relationships. These are used in succeeding pages to organize the presentation of data. Finally, the categories were further refined to create assertions accommodating all of the data, which may be found in the discussion.

Presentation of Data. No two teachers defined or used science writing in the same ways. Although each of the four teachers indicated that writing was a part of their science instruction and that their students were learning science through writing, each defined the reasons, purposes, and audience for that writing in a slightly different manner. Interestingly, none questioned whether the students in his/her class understood the teacher's reasons for including writing in science class, or whether the intended uses of the products were interpreted in the same manner by students and teachers.

Ellen included writing in science because

> It's a way for them [students] to look for answers to their own questions. Writing can be a very analytical process. They have to read sources carefully, learn how to take notes and put things together, try taking on some different perspectives ... It's not just answering my questions. That's a lot easier.

Like Ellen, Claudia felt that writing of all sorts belonged in the curriculum. Science writing, she indicated, was a way of applying science to solve problems, of recording the relationships identified as important by the teacher. "I think writing helps kids to straighten out their thinking. If they know they have to write about something, they listen a little harder and pay attention to more details."

Jim thought of writing as a form of assessment that gave students practice in using the skills taught in other classes. Writing, he felt, "gives something to back up a grade in class. ... I like short answer questions best. They give a student a little bit of room to express himself and I can still tell if he knows his stuff or not."

The science writing of Tammy's students occurred at home. After a Friday science class, Tammy sent home the blackline masters provided by the textbook company.

> I think if I didn't send it home, the parents wouldn't have a clue what they do in here. I had a parent ask me once if we did any science at all. I felt really bad that they'd think I'd leave it out.

Tammy and Jim's reasons for including writing in their science program are particularly interesting in that they have little or nothing to do with the relationship between writing and learning. Both commented on the relationship between writing and professional accountability, which was not mentioned by Claudia or Ellen.

Most teachers found responding to science writing to be a frustrating process. Although Ellen confidently wrote personal letters to her students, responding to both content and process, the other teachers were more reluctant to commit themselves on paper. The discomfort articulated by the other teachers related to issues of time, accountability, and power. Their written responses were cursory, sometimes just letter grades or check marks. None of the teachers indicated the criteria on which their evaluations were based. Jim, Tammy, and Claudia voiced a degree of antipathy toward the whole idea of responding to formative science writing. Tammy, who flatly stated at the outset that she had no interest in writing as a part of science learning, did not waver in her opposition to its inclusion in the curriculum at her grade level.

> Time, that's the whole issue. That and who's going to be responsible if some kid doesn't learn it like they all [curriculum developers] say it's supposed to happen. I just don't see why this has to happen in this grade. Let [junior high teachers] teach them how.

Although interested in the idea of learning through the process of writing, Jim and Claudia felt that in-depth responses might be counterproductive to learning. Jim was concerned about the use of the product for assessment of science knowledge. He wanted to be sure, he said, that a student's work was truly his own. Mightn't a change in text following formative feedback reflect what the teacher knew rather than what the student knew? Claudia, on the other hand, felt that student learning was a personal process and wanted to interfere as little as possible. She felt that extensive teacher feedback might limit the range of ideas a young writer would consider in future writing. She did not want to exert excessive influence on the students' expression.

Reading and responding to the INSECTS journal entry (Figure 2) seemed to provoke the most ambivalence among the teachers. Jim groped for words to express his response:

> I can tell that this kid's really excited, really enthusiastic about insects. There's just a real sense of energy here. But it doesn't really tell me anything. I gave this one a 'D' and I wrote this on it, 'You've got some neat ideas but it's hard to understand.' ... If he was in my class, I wouldn't accept this paper. I can't grade it because there's nothing really here.

Claudia, looking at the same piece of writing, interpreted it differently. "B+," she scrawled in green marker across the top of the page. "You have a real feel for how insects live!" Later, talking about the INSECTS piece, she pointed out that

> It's very hard to know how to look at a piece of writing. ... If this was a kid that has trouble writing, ... then I'd want to be sure to comment on the positive things. ... But if it's a kiddo who is usually a good writer and is just being lazy about this report, I think I need to let him know it's hard to understand.

Tammy was stymied by the INSECTS paper. She penned a small red "S" and drew a round face with a straight line for a mouth. "Do I grade the English? That's pretty bad! ... Or do I grade the science? Well, then it's not real great either, because the kid can't write very clear."

Ellen, who had the advantage of knowing both the writer and the formative nature of the piece, responded by urging the author to consider the needs of a reader for organization and clarity. In a two-paragraph letter to the author, she expressed her fascination with the information in the report, then asked focused questions to guide further revision.

> I was fascinated by the information that you shared. You leave me ... with some immediate questions. ... You mention that ... insects have three body parts and eyes with many lenses. Are there other characteristics of an insect? I think it would be helpful to make a list of those for yourself and the audience.

No grade was attached to Ellen's response. "I think that when a student has to be conscious of whether his work is just what the teacher wants to see he loses sight of what is supposed to be happening—the learning." Interestingly, Claudia's similar feelings about children's need to direct their own learning led to her almost total "hands off" policy in grading.

All four teachers felt that their written responses to INSECTS were inadequate. "You just have to talk to the kid," Claudia felt. These words make sense when the class is self-contained and fairly small. But Jim, who teaches six different groups of students each day, rarely learns the names of his students before the winter holiday. He is conscious of his inability to respond on a personal level to even the brief assignments he currently assigns.

> It's just not possible. Even if I wanted to (and I'm not sure I really do), I couldn't write anything useful on every student's paper. I'd be at it for hours! And I'm not sure they'd even bother to read it in the end.

Tammy, whose overfilled class meets in a doublewide trailer on a concrete parking lot, commented, "I don't have time to grade their handouts now. How could I grade something like this?"

All of the teachers assumed the students could read and write nonfiction science paragraphs and were uncomfortable with evidence that this might not be the case. All four teachers indicated that they responded first to the manner in which a given piece was written and then to the science content. Their discomfort with this was clear from their actions. Jim thrust his hand, palms up, into the air in a silent entreaty as he tried to explain his reasoning. Claudia looked out the windows of her classroom, chewing on her lip. Tammy rummaged in her desk, doodling with one pen after another as she spoke in rapid-fire incomplete sentences. Ellen looked down at her hands for a long time before speaking. The INSECTS piece flapped in her hand as she tried to explain her conflict.

> I don't want to be an English teacher all the time. But ... I can't get away from it. I pay a lot of attention to their words, and when the words aren't put together very well, it does matter to me.

All four of the teachers anticipated a general-to-specific paragraph structure, with a conventional topic sentence and explanatory examples in the following sentences. Jim and Tammy were uncertain about the relationship between writing ability, terminology, and the writer's understanding of the ideas they conveyed. Tammy pointed out that OCEANS was "pretty well written, ... they used the right vocabulary words, ... but some things don't make sense."

Jim faltered, tapping SUNS against his palm.

> There's some facts here. They don't go together very well. I've been sitting here trying to figure out if I'd grade it differently if the words and the sentences were hooked together better ... if the kid was a better writer ... and I think that I would. I can't tell if he's really saying what he's thinking (and just isn't thinking very much) or if he really knows a lot and just can't get it on paper.

The teachers all responded positively when students used accurate terminology. "GREAT!" Jim wrote when he read the word colony. "I expected *hive*," he explained, "But *colony* is just what this kid meant."

Claudia penned, "I didn't know that!" beside a passage citing the defining qualities of fish. "This is good stuff," she later commented.

Claudia, Jim, and Tammy were equally severe in their censure of seemingly sloppy connections expressed in the writing samples. After struggling for several minutes to put words to her frustrations after reading INSECTS, Claudia puffed out her cheeks and blurted, "Isn't this stuff they learned in first grade? Why is this kid writing about this now, in fifth grade, and getting it wrong at that?"

Jim pointed to the SUN piece in disgust and said, "This is just junk. This kid's trying to blow me away with all these numbers. So what? They're in the third grade textbook. Tell me something new, kid, like tell me HOW the sun makes all that heat."

Jim was openly puzzled by the children's errors in science language. "Now why do you suppose she wrote THAT?" he asked at one point. "She obviously knows a lot about the ocean, so why doesn't she say it the right way?"

The three female teachers regarded science writing as qualitatively different from other nonfiction writing. Ellen and Tammy spoke of learning as a process that was different for each of the content areas. Ellen in particular noted that science caused some children great difficulty.

> I try to give LOTS of time and help when we do science writing. I schedule it later in the year than ... family stories. With science they really have to do research. They have to read what other people have written about airplanes or horses, then they have to figure out what's important or surprising. It's just not easy.

Tammy regarded science as "very hard" to write about. As she discussed the various pieces, she wondered aloud whether it was "fair" to ask children to write about science.

> It's not something they're born knowing how to do. ... There are some rules for science writing that's the same in every science book. Why can't the kids just learn that way? But later, I don't think they have enough to say yet, so they get all mixed up trying to make it sound fancy.

Claudia, too, felt that writing in science class was different than writing in, say, history class.

> I'm always concerned when I read about this. I want it to work ... but I see it in every area of my curriculum EXCEPT science. ... They get all bollixed up in the writing and lose sight of the great ideas they're trying to tell about. When we write about the raccoons in the dumpsters, it doesn't happen, but when they try to write the same thing like a science report and not a story, they're all messed up again.

Discussion

It is not surprising that Ellen, Jim, Tammy, and Claudia varied in their responses to the pieces of science writing which were used as prompts for this study. The teachers were, after all, selected as extreme cases of self-reported qualities associated with their science knowledge (number of college science courses), pedagogical knowledge (number of years teaching at the intermediate level), and philosophy (interest in science writing). My hope as I began was to uncover a range of personally relevant catalysts and impediments to teaching practices associated with writing to learn. Surprisingly, though, only two factors emerged: the degree of congruence between the

teachers' personal definitions of science and that underlying the writing to learn approach and the needs of individual teachers for external supports as they teach science.

The teachers' individual definitions of science predisposed them to either accept or reject the processes of science writing as supportive of science learning. It is significant that the teacher who took the largest number of college science courses and had the greatest interest in science in everyday life also had the greatest interest in science writing. To Ellen, science, like history or geography, was one of many useful perspectives on the world. Like the other disciplines, science has an associated vocabulary, tools, and conventional processes. Perspectives, she felt, were best explored through authentic experience in using their tools—including language forms. She traced her unusual definition of science to continuing contact with the university's science and language education departments and a strong background in basic elementary subjects.

Although Claudia was extremely interested in applied science, she defined science as content to be learned through direct experience. Like Jim and Tammy, Claudia found that her personal definition of science and science writing was in conflict with the process approach of the new curricular stance of the district. The three teachers thought of writing as a way to express what was already known about science through the specialized language that constituted their own childhood science instruction. When asked by their administrators to use writing as a way to learn in all areas of the curriculum, the three did not consider types of writing other than the formalized reports of knowledge with which they were comfortable. They took the mandate to mean that the district assumed that children could be expected to learn science through writing *without significant alteration of the teaching stance or content.*

As Ellen, Jim, Tammy, and Claudia demonstrated, the teaching stance supportive of Writing to Learn is far from common, however. It arises from a philosophy of learning and teaching that personalizes instruction, requires extensive investment of time and individual attention from the teacher, and places each child's prior experiences at the center of the science lesson. Only Ellen, who described her classroom as "intentionally democratic," authentically integrated writing into science teaching and learning: the other teachers veneered writing onto traditional teaching relationships and science teaching practices.

The teachers' needs for external support in science teaching and assessment defined the range of learning activities which they included in science instruction. Ellen's extensive undergraduate science education helped her develop a sense that communication was a vital aspect of science, one critical component of her ready adoption of Writing to Learn. It also provided her with basic knowledge of the content and processes of science that allowed her to move away from the textbooks provided by the school district without feeling she was compromising student learning. Her knowledge of state and national standards allowed her to plan science instruction that dipped in and out of several science kits, used trade books and community experiences as springboards for thematic inquiries, and considered topics in far greater depth and breadth than traditional for the fifth grade. Her students consistently scored very well on the science sections of standardized tests of achievement.

Jim, Tammy, and Claudia did not regard the district's curricular mandate as permission to alter what they saw as defining qualities of the instructional relationship, including the use of textbooks, teacher-determined content, lectures, group instruction, and grades. They relied on that relationship in all subjects, but none more than science with its (to them) remote theories and extensive vocabulary.

Two policy implications may be drawn from the experiences of Jim, Tammy, and Claudia as they responded to children's science writing. First, moving into non-textbook science teaching is not adequately facilitated by district-wide inservice sessions. Jim, Tammy, and Claudia felt they needed informational support as well as the content limitation of the basal text series, as their own knowledge of science did not extend much farther than that of most of their students. They needed to determine the content in advance so that they could prepare worksheets, activities, and tests. They relied on lecturing because they did not trust, as Ellen did, that their students would be exposed to the required concepts and vocabulary from curriculum resources beyond their direct control. Group instruction was a necessity given their assumption that learning could only occur if a teacher was involved; grades were a given, a part of public schooling that was beyond question, all of which suggests a continuing need for pedagogical guidance.

Although Tammy and Claudia indicated that part of their resistance to nontextbook science teaching related to a need for greater understanding of science, they rejected the idea of continuing education in science. For Jim, Tammy, and Claudia, seeking out continuing education betrayed incomplete knowledge, which was inconsistent with professionalism. Although their need, perhaps the need of most elementary generalists, is for very basic experiences with science, their school district reimburses teachers for graduate coursework only. This has contributed to a self reinforcing cycle in which teachers with minimal topical science knowledge restrict the range of experiences available to their students to those producing results with which they are familiar. An alternative might be for the local university and school district to jointly plan a graduate course combining pedagogical techniques and basic science instruction.

Secondly, Jim, Tammy, and Claudia need explicit support as they alter the traditional relationships between students, teachers, and curriculum in their individual classrooms, and this must come from the administrators on whom they rely for evaluation—the building principals. It was a strong principal who recognized Ellen's propensity for individualizing and gave her permission to follow her professional judgment in moving away from textbooks. If other experienced teachers are to feel that student-centered education and the associated shift of focus away from teacher control are genuinely desirable, it must be explicitly encouraged and given substance in discussions of professional performance.

While the factors influencing teaching decisions are many, one of the greatest barriers to reform in science education may well be Tammy's fear (echoed in some form by each participant) that "it doesn't really matter what I do, ... it'll be wrong." She sees the profession of teaching as a career of making the "less wrong choices" for her students. Schools of Education, school administrators, and teacher advocacy groups must listen to the concerns of the Tammys, Claudias, Ellens, and Jims of this world and communicate a consensus of the "right choices." Unless educational reforms are perceived by typical teachers as genuinely available alternatives supported by those who evaluate their professional performance, fears like these will ultimately determine both the course and pace of educational change.

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